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• **KITANO, Kouji**

Nikko Materials Co., Ltd GNF Plant

Hitachi-city Ibaraki 317-0056 (JP)

(30) Priority: **05.04.2000 JP 2000103508**

(74) Representative: **Meddle, Alan Leonard**

Forrester & Boehmert

Pettenkoferstrasse 20-22

80336 München (DE)

(71) Applicant: **Nikko Materials Company, Limited**
Tokyo 105-8407 (JP)

(72) Inventors:

• **SAKAMOTO, M.**

Nikko Materials Co., Ltd. GNF Plant

Hitachi-city, Ibaraki 317-0056 (JP)

(54) COPPER-CLAD LAMINATED SHEET

(57) There is provided a copper clad laminate which makes laser beam drilling extremely easy and is suitable for forming an interlayer connection microhole by improving a surface of its copper foil, which is to be used as the surface which a laser beam enters, in the production of printed circuit boards. Specifically, the copper

clad laminate is such that it includes electrodeposited copper foil for use in the laser beam drilling and is characterized in that the matte side of the above electrodeposited copper foil is used as the surface which the laser beam enters.

EP 1 272 017 A1

Description**BACKGROUND OF THE INVENTION**5 **Field of the Invention**

[0001] The present invention relates to a copper clad laminate excellent in hole processability in laser beam drilling which provides efficient formation of an via-hole in a printed circuit board.

10 **Description of the Prior Art**

[0002] Recently, with the increasing wiring density, the laser beam drilling, which allows a finer processing than the conventional mechanical drilling, has been used more frequently in the production of electronic components and wiring boards both utilizing copper foil as a conductor.

15 **[0003]** However, when drilling a hole in a copper foil surface by illuminating the same with the carbon dioxide laser beam excellent in general-purpose properties, the reflectance of copper reaches almost 100 % at the wavelengths of the carbon dioxide laser beam, that is, around 10 μm , leading to a problem of extremely low laser processing efficiency.

[0004] In order to offset such a decrease in processing efficiency, a high output carbon dioxide laser drilling machine is required; however, when performing laser processing with high energy of such a high output carbon dioxide laser
20 drilling machine, the resin board subjected to drilling simultaneously with the copper foil is drilled to excess and damaged, which gives rise to a problem of being unable to drill a hole of intended shape.

[0005] Further, the amount of the splashed matter accompanying the laser processing becomes larger, which causes another problem of, for example, contamination of the laser drilling machine as well as the non-processed portion of the material having been subjected to the processing.

25 **[0006]** So, in order to avoid these problems, an attempt has been made to first make a hole in the copper foil portion by the chemical etching and then drill the resin portion by the laser beam. In this case, however, the number of the processes becomes larger than that of the case where the copper foil and the resin portion are drilled at a time, causing an increase in costs. Thus, this attempt also has a disadvantage.

[0007] On the other hand, as means for laser-processing a metal exhibiting a high reflectance at the laser beam
30 wavelengths, a method has generally been adopted in which the surface of the metal is provided with a material with high absorptivity, so as to allow the material to absorb the laser beam and generate heat, and with the heat the metal is processed. Further, it has been known that roughing the material surface also allows a high processing efficiency.

[0008] Further, there has been proposed a method in which the surface of the copper foil is subjected to oxide treatment (black oxide treatment method) at the time of drilling, in order to increase the processing efficiency.

35 **[0009]** However, with any of the above proposals, the operations and treatments become complicated, and a sufficient laser processing efficiency cannot be obtained, considering how complicated they are. In addition, in the copper foil provided with the above-described surface treatment layer, the treatment layer tends to peel off since it is quite brittle and become a contamination source during the processing, which gives rise to another problem.

[0010] Further, there has been proposed a method in which copper foil itself is made thin so that it can be drilled by
40 a low energy laser beam. However, since the thickness of the copper foil actually used varies from 9 μm to 36 μm , the copper foil can be made thin only for some cases. Furthermore, in order to perform drilling under such low energy conditions, the copper foil required to be as extremely thin as 3 to 5 μm , which causes another problem of handling etc.

[0011] As described so far, although there has been proposed several methods of improving the copper foil in current use, the present situation is that any of the methods is not satisfactory for the laser beam drilling, in other words, the
45 copper foil materials suitable for the laser processing have not been obtained yet.

BRIEF SUMMARY OF THE INVENTION**Object of the Invention**

50 **[0012]** The present invention has been made in light of the above-described problems. Accordingly, the object of the present invention is to provide a copper clad laminate which makes the laser beam drilling extremely easy and is suitable for forming an interlayer connection microhole by improving the surface of its copper foil, which is to be used as the surface which the laser beam enters, in the production of printed circuit boards.

55 **Summary of the Invention**

[0013] The present invention provides:

1. a copper clad laminate including an electrodeposited copper foil for use in laser beam drilling, characterized in that a matte side of the above electrodeposited copper foil is used as a surface which a laser beam enters;
2. the copper clad laminate according to the above description 1, characterized in that a surface roughness R_z of the matte side of the above electrodeposited copper foil is $2.0\text{ }\mu\text{m}$ or more;
3. the copper clad laminate according to the above description 1 or 2, characterized in that the matte side of the above electrodeposited copper foil is subjected to additional roughening treatment by the electrodeposition;
4. the copper clad laminate according to any one of the above descriptions 1, 2 and 3, characterized in that a shiny side of the above electrodeposited copper foil is subjected to roughening treatment by electrodeposition; and
5. the copper clad laminate according to the above description 3, characterized in that roughening treatment is performed using any one or more of Ni, Co, Sn, Zn, In and alloys thereof as metals for use in the electrodeposition.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] Generally electrodeposited copper foil is produced by electrodeposition of copper on a drum, and one side of the electrodeposited copper foil in contact with the drum becomes a shiny side which is relatively flat and the other side exposed to an electrolysis solution becomes a matte side. When using this electrodeposited copper foil in a copper clad laminate, its matte side becomes a surface adhering to a resin of the laminate, on the other hand, its shiny side becomes a surface which a laser beam of, for example, carbon dioxide enters.

[0015] As described above, the copper foil itself has low absorptivity to the laser beam; accordingly, it is only natural that its shiny side is more difficult to make a hole by laser beam drilling. However, it has been found that if the shiny side is plated with particulate matter to 0.01 to $3\text{ }\mu\text{m}$ thick so as to form roughness thereon, its hole processability can be improved.

[0016] This fine roughness reflects the laser beam diffusely and can produce the same effect as that of the laser beam absorption, therefore, it is a very effective means for ensuring satisfactory hole processability even when drilling is performed by low energy laser beam such as carbon dioxide laser beam.

[0017] However, in order to ensure satisfactory hole processability by providing a flat shiny side of the electrodeposited copper foil with the above-described roughness through electrodeposition, the electrodeposition conditions of the treatment solution composition etc. are required to be strictly controlled. For example, when performing electrodeposition under such conditions that the roughness of the treated layer is made large in order to enhance the hole processability in the laser beam drilling, there arises a problem such that peel-off and dislodgement of the treated layer are likely to occur.

[0018] This peel-off and dislodgement of the treated layer can be gotten rid of to a considerable extent by allowing the electrodeposition composition to contain a copper component. On the other hand, in some cases, the electrodeposition composition is allowed to contain a large quantity of metal components other than copper so as to enhance the hole processability of the copper foil; however, in this case, the peel-off strength and dislodgement strength of the surface layer are decreased, leading to a big problem.

[0019] Thus, when using the shiny side of the electrodeposited copper foil as the surface which the laser beam enters, how the hole processability in the laser beam drilling and the adhesion strength of the surface layer should be made compatible with each other remains an open question. This is true of rolled copper foil.

[0020] When using electrodeposited copper foil in a copper clad laminate, according to the prior art, the matte side of the electrodeposited copper foil is used as the surface for bonding the electrodeposited copper foil and the resin of the laminate to each other and the shiny side of the same as the surface which the laser beam such, as carbon dioxide laser beam, enters; however, in the present invention, viewing this matter from a quite opposite angle, the matte side of the electrodeposited copper foil is used as the surface which the laser beam enters and the shiny side of the same as the surface for bonding the electrodeposited copper foil and the resin of the laminate to each other.

[0021] Thus, the bonding function of the matte side of the electrodeposited copper foil attendant on its adhesion strength is lost; however, the resin for use in copper clad laminates has been much improved in adhesion properties and strength and lately many copper clad laminates have not been required to have so high adhesion strength as before.

[0022] According to need, particulate projections (knotty projections) can be formed on the shiny side of the electrodeposited copper foil, through which the electrodeposited copper foil and the resin are bonded together, by electrodeposition to form roughness thereon, thereby the adhesion properties can be improved. Accordingly, in improving the adhesion properties of the shiny side to the resin, electrodeposition does not need such strict control as the case where the shiny side is used as the surface which the laser beam enters does; therefore, the use of the shiny side as the surface for bonding is not a big problem.

[0023] In this case, the electrodeposit does not appear on the surface layer of the copper clad laminate since it adhered to the resin of the same; therefore, the problem such that the rough portion on the surface layer of the copper clad laminate peels off and dislodges will not occur directly during the laser beam illumination.

[0024] The matte side of the electrodeposited copper foil for use in a copper clad laminate produces a satisfactory

effect in improving the hole processability of the copper clad laminate in the carbon dioxide laser beam drilling, if its surface roughness Rz is 2.0 μm or more. The matte side formed during the formation of electrodeposited copper foil is originally part of the copper foil, accordingly, there occurs neither peel-off nor dislodgement therein.

[0025] The roughness of the matte side varies depending on the composition of the electrolysis solution and the current conditions, and there exists electrodeposited copper foil of which matte side has such a small surface roughness as is close to that of the shiny side. Even in that case, as long as the surface roughness Rz is 2.0 μm or more, the copper clad laminate is provided with satisfactory hole processability.

[0026] Further, when intending to improve the hole processability in the laser beam drilling, metal electrodeposit (an electroplated layer) can be newly formed on the matte side. This additional roughening treatment produces a satisfactory effect even if the quantity of the electrodeposit is far smaller than that of the case where roughness is formed on the shiny side.

[0027] There already exists roughness on the matte side of electrodeposited copper foil which has been formed by the electrodeposition during the formation of the electrodeposited copper foil, therefore, the additional formation of particles thereon can be performed at a lower current and a lower deposition rate than the formation of the same on a flat surface. Accordingly, it becomes easier to set the electrodeposition conditions under which neither peel-off nor dislodgement occurs.

[0028] This additional roughening treatment can improve the hole processability of the matte side of the electrodeposited copper foil not only when electrodepositing Cu to form particulate projections (knotty projections), but also when electrodepositing Ni, Co, Sn, Zn, In and the alloys thereof, all which have high laser beam absorptivity.

[0029] The electrodeposition of the above high absorptive materials may be performed after forming the above-described particulate projections (roughness) by Cu electrodeposition.

[0030] Desirably the thickness of the electrodeposited copper foil for use in the present invention is 18 μm or less, in view of its application as high density wiring. However, for the copper foil of the present invention having improved hole processability, its thickness is not limited to the above values, but the present invention applies to the copper foil with thickness more than 18 μm .

[0031] In the following, one example of the conditions will be shown under which roughening plating is performed using copper. The conditions themselves are well-known ones.

(Water-soluble Copper Sulfate Plating Bath)

[0032]

$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$: 23 g/l (as Cu)

NaCl: 32 ppm (as Cl)

H_2SO_4 : 70 g/l

Glue: 0.75 g/l

Deionized water: Bal.

(Plating Conditions)

[0033]

Current density: 60 to 100 a.s.f

Duration: 10 to 60 sec.

Bath temperature: 70 to 80°F

[0034] After completing the above electrodeposition, anti-corrosive treatment can be applied with a treatment solution containing chromium and/or zinc. The method of the anti-corrosive treatment or the treatment solution used therein is not limited to any specific one. This anti-corrosive treatment can be applied partially to the above electrodeposited surface, that is, the portion of the copper foil surface receiving the incident laser beam or to the entire copper foil surface.

[0035] Like the roughening treatment described above, it goes without saying that the anti-corrosive treatment should not destroy the properties which the copper foil applied to printed circuit boards should have, and the anti-corrosive treatment of the present invention fully satisfy this requirement. This anti-corrosive treatment hardly affects the hole processability of the copper foil in the laser beam drilling.

[0036] As a typical example of the plated layers consisting of Ni, Co, Sn, Zn, In and the alloys thereof which are used in the electrodeposition to enhance the laser beam absorptivity of the matte side of the copper foil, there is a copper-cobalt-nickel plating layer, and the conditions of the copper-cobalt-nickel plating treatment are shown below.

[0037] This example is shown as a preferred example for illustrative purpose only and is not intended to limit the

present invention.

(Cu-Cobalt-Nickel Plating Treatment)

5 [0038]

Co concentration: 1 to 15 g/L, Ni concentration: 1 to 15 g/L

Cu concentration: 5 to 25 g/L

Electrolysis solution temperature: 20 to 50°C, pH: 1.0 to 4.0

10 Current density: 1.5 to 30 A/dm², Plating duration: 1 to 180 seconds

[0039] As the anti-corrosive treatment of the present invention, the plating treatment shown below, which is a typical example, is applicable. This example is shown as a preferred example for illustrative purpose only and is not intended to limit the present invention.

15

(Chromium Anti-corrosive Treatment)

[0040]

20 K₂Cr₂O₇ (Na₂Cr₂O₇ or CrO₃): 2 to 10 g/L

NaOH or KOH: 10 to 50 g/L

ZnO or ZnSO₄ · 7H₂O: 0.05 to 10 g/L

PH: 3.0 to 4.0, Electrolysis solution temperature: 20 to 80°C Current density: 0.05 to 5 A/dm², Plating duration: 5 to 30 sec.

25

[Examples]

[0041] In the following, the present invention will be described based on the examples. It is to be understood that these examples are shown as preferred examples of the present invention and not intended to limit the same, and that various changes and modifications may be made therein without departing from the spirit and the scope of the invention.

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[0042] For comparison, comparative examples will be added in the latter part.

(Example 1)

35

[0043] A copper clad laminate including electrodeposited copper foil 12 μm thick in which the matte side of the electrodeposited copper foil was used as the surface subjected to laser beam illumination (the shiny side of the same being bonded to the resin of the laminate). The surface roughness Rz of the matte side was 2.2 μm.

(Example 2)

40

[0044] A copper clad laminate including electrodeposited copper foil 12 μm thick in which the matte side of the electrodeposited copper foil was used as the surface subjected to laser beam illumination (the shiny side of the same being bonded to the resin of the laminate). The surface roughness Rz of the matte side was 3.0 μm.

45

(Example 3)

[0045] A copper clad laminate including electrodeposited copper foil 12 μm thick in which the matte side (with surface roughness Rz 3.0 μm) of the electrodeposited copper foil was subjected to roughening copper plating under the above-described conditions to deposit copper particles thereon, and the roughened surface was used as the surface subjected to laser beam illumination. The surface roughness Rz of the roughened surface was 3.5 μm.

50

(Example 4)

[0046] A copper clad laminate including electrodeposited copper foil 12 μm thick in which the matte side (with surface roughness Rz 3.0 μm) of the electrodeposited copper foil was subjected to roughening copper plating under the above-described conditions to deposit copper particles thereon, the roughened surface was further subjected to copper-cobalt-nickel alloy plating under the above-described conditions, and the plated surface was subjected to laser beam illumination. The surface roughness Rz of the roughened surface was 3.7 μm.

55

(Comparative Example 1)

[0047] A copper clad laminate including electrodeposited copper foil 12 μm thick in which the shiny side of the electrodeposited copper foil was used as the surface subjected to laser beam illumination. The surface roughness Rz of the shiny surface was 1.4 μm .

(Comparative Example 2)

[0048] A copper clad laminate including electrodeposited copper foil 12 μm thick in which the shiny side (with surface roughness Rz 1.4 μm) of the electrodeposited copper foil was subjected to copper-cobalt-nickel alloy plating and the plated surface was used as the surface subjected to laser beam illumination. The surface roughness Rz of the plated surface was 1.7 μm .

[0049] The composition of the copper-cobalt-nickel alloy was the same as the above-described example 3, and the plating was applied such an extent that the laser beam opening ratio became almost the same as that of example 3.

[0050] The samples of above examples 1 to 4 and comparative examples 1,2 were formed into single sided boards using a prepreg (FR-4), and 100 spots per board were illuminated with the laser beam under the following conditions and their opening ratio were compared. The results are shown in Table 1.

(Laser Illumination Conditions)

[0051]

Machine used: Carbon dioxide laser beam machine

Spot size: 144 $\mu\text{m}\phi$

Pulse width: 32 μsec

Frequency: 400Hz, Shot number: 1 shot

Laser beam illumination energy: 13 mJ/ shot, 21 mJ/ shot, 32 mJ/ shot, 42 mJ/ shot

[Table 1]

	Roughness of Illuminated Surface	Laser Beam Opening ratio	Laser Beam Opening ratio	Laser Beam Opening ratio	Laser Beam Opening ratio	Powder Drop-off Test
	Rz/ μm	13 mJ/shot	21 mJ/shot	32 mJ/shot	42 mJ/shot	
Example 1	2.2	0%	0%	21%	100%	○
Example 2	3.0	0%	2%	100%	100%	○
Example 3	3.5	4%	100%	100%	100%	○
Example 4	3.7	100%	100%	100%	100%	○
Comparative Example 1	1.4	0%	0%	0%	98%	○
Comparative Example 2	1.7	100%	100%	100%	100%	×
○ No Powder Drop-off x A large amount of Powder Drop-off						

[0052] In example 1, the surface which the laser beam entered was the matte side (Rz 2.2 μm) of the copper foil as it was. The opening ratio was 21 % at a laser beam energy of 32 mJ/shot and reached 100 % at 42 mJ/shot. No powder drop-off (peel-off and dislodgement of the surface layer) was observed.

[0053] In example 2, the surface which the laser beam entered was the matte side with surface roughness Rz 3.0 μm . The opening ratio was 2 % at a laser beam energy of 21 mJ/shot and reached 100 % at 32 mJ/shot. No powder drop-off (peel-off and dislodgement of the surface layer) was observed.

[0054] In example 3, the surface which the laser beam entered was the matte side having been subjected to roughing copper plating to deposit additional copper particles thereon and having surface roughness R_z 3.5 μm . The opening ratio was 4 % at a laser beam energy of 13 mJ/shot and reached 100 % at 21 mJ/shot. It is evident that the opening ratio was improved. No powder drop-off (peel-off and dislodgement of the surface layer) was observed, like the example 1.

[0055] In example 4, the surface which the laser beam entered was the matte side having been subjected to roughing copper plating to deposit additional copper particles and further subjected to copper-cobalt-nickel alloy plating. The opening ratio reached 100 % at 13 mJ/shot. It is evident that the opening ratio was much more improved than example 3 and a hole can be made in the surface even with the low energy laser beam. No powder drop-off (peel-off and dislodgement of the surface layer) was observed.

[0056] In comparative example 1, the shiny side of the copper foil was used as the surface which the laser beam entered. It goes without saying that no powder-off was observed. The opening ratio was 98 % even at a laser beam energy of 42 mJ/shot and, even if the output of the laser beam was increased, satisfactory opening ratio was not obtained.

[0057] In comparative example 2, the surface which the laser beam entered was the shiny side of the copper foil having been subjected to copper-cobalt-nickel alloy plating to form a particle layer thereon. Since the plating was applied to such an extent that its opening ratio reached the level of example 4, peel-off and dislodgement of the plated layer were extreme and powder drop-off occurred due to even a slight rub, which was a cause of contamination.

[0058] In addition, there arose a problem of a decrease in opening ratio at the portion where the peel-off and dislodgement occurred.

[0059] Although the above-described examples do not cover a wide range of plating types, in any type of the plating shown above, the similar effects were obtained.

[0060] As is evident from the above, excellent laser beam opening ratios can be obtained using the matte side of electrodeposited copper foil of which surface roughness R_z is 2.0 μm or more as the surface subjected to laser beam illumination. In addition, the laser beam opening ratio can be further enhanced by subjecting the above matte side of electrodeposited copper foil to roughening treatment by the electrodeposition.

[0061] In the production of printed circuit boards, the present invention allows making a hole directly in copper foil and forming an via-hole in a simple and convenience manner by the low energy laser beam drilling using, for example, carbon dioxide laser beam, in addition, it is remarkably effective in preventing the peel-off and dislodgement of the plated layer caused by a rub.

Claims

1. A copper clad laminate comprising an electrodeposited copper foil for use in laser beam drilling, wherein a matte side of said electrodeposited copper foil is used as a surface which a laser beam enters.
2. The copper clad laminate according to claim 1, wherein surface roughness of the matte side of said electrodeposited copper foil is 2.0 μm or more.
3. The copper clad laminate according to claim 1 or 2, wherein the matte side of said electrodeposited copper foil is subjected to roughening treatment by electrodeposition.
4. The copper clad laminate according to any one of claims 1, 2 and 3, wherein a shiny side of said electrodeposited copper foil is subjected to roughening treatment by electrodeposition.
5. The copper clad laminate according to claim 3, wherein the roughening treatment is performed using any one or more of Ni, Co, Sn, Zn, In and the alloys thereof as electrodepositing metals.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP01/02707

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl.⁷ H05K 3/00, B32B15/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl.⁷ H05K 3/00, B32B15/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1926-1996 Toroku Jitsuyo Shinan Koho 1994-2001
Kokai Jitsuyo Shinan Koho 1971-2001 Jitsuyo Shinan Toroku Koho 1996-2001

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, 5545466, A (Mitsui Mining & Smelting Co., Ltd.), 13 August, 1996 (13.08.96), & JP, 6-270331, A & EP, 616489, A & AT, 155311, T & ES, 2105046, T & KR, 127665, B	1-5
Y	JP, 10-178253, A (Santa Keikinzoku Kogyo K.K.), 30 June, 1998 (30.06.98) (Family: none)	1-5
Y	JP, 4-356993, A (Hitachi Seiko Ltd.), 10 December, 1992 (10.12.92) (Family: none)	3, 5
Y	JP, 11-266068, A (Canon Inc.), 28 September, 1999 (28.09.99) (Family: none)	5

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:
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